The Contribution of Northern US Geodetic Data to the Study of Vertical Deformations of the Crust in Canada

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Introduction:

Accurate estimates of the rate of vertical crustal deformations due to Glacial Isostatic Adjustment (GIA) in Canada are needed for many practical and scientific reasons. We used relevelled segments covering the period from1909 to 2003 and historical tide gauge records to determine the map of vertical crustal movements (VCM) for the region. However, due to the lack of data in the central part of Canada, the estimates of postglacial rebound are uncertain in this area. In Eastern and western parts of the Great Lakes, for example, there are not enough Canadian relevelled segments. On the other hand, it is known that the postglacial rebound zero line passes through the Great Lakes and that the precise locationg of the zero line depends highly on the contribution of US tide gauge records. Distribution of Canadian geodetic data is shown in figure 1.

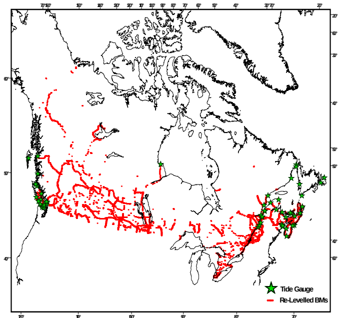

Figure 1: Distribution of Canadian Geodetic data

This work explores the benefits of incorporating US historical tide gauge records with longer records compared to Canadian tide gauges, which give more constraints in the east and west of the map, particularly in the determination of absolute velocity in the region. In addition, incorporating northern US relevelling data is determineded to be useful in support of the map of VCM in Canada from the south.

Water level data: The Canadian sea level information analyzed in this study includes monthly tide gauge values recorded at historical tide gauges, and was provided to us by Marine Environmental Data Service (MEDS). Monthly mean sea level data for the US tide gauges are available from the National Oceanic and Atmospheric Administration (NOAA). We used the monthly mean sea level data for the historical tide gauges above 43 degrees latitude. This includes 8 tide gauges on the Atlantic Ocean, 2 on the Arctic and Hudson bay, and 10 on the Pacific ocean. As well, monthly mean values for the gauges in the Great Lakes are published by NOAA.

Geodetic re-levelled segments: The original Canadian 1st order leveling database was provided to us by Geodetic Survey Division (GSD) of Natural Resources Canada. The National Geodetic Survey (NGS) provided us with US levelling data within about 150 km from the Canadian border. The data were given in many files. The files are named by their identifiers which makes it difficult to search for the leveling segments that were carried on over more than one epochs. Figure 2 shows the map of US geodetic data near the Canadian border.

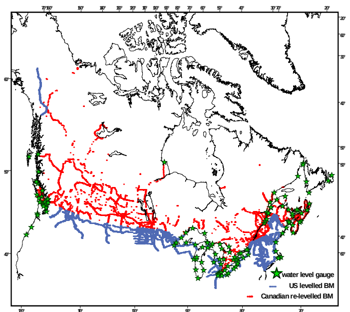

Figure 2: The distribution of all available Geodetic data in Canada and the northern US.

Incorporating US water level data in the network of the optimum differencing:

We use the method of differencing to treat the sea and the lake level trends in nearby tide gauges to cancel out the common atmospheric and oceanic noises. Mean sea level trend of one tide gauge is used as a point velocity and the rest of tide gauge records are differenced to obtain velocity differences. We compute the Pearson Linear correlation coefficient for any pair of series to find out the optimum network of tide gauges for differencing (Vanicek et al., 1993). In the Pacific coast, for example, we found out that the smallest standard deviation is associated with the linear trends of Seattle, Wa. Table 1 lists the linear trends of the tide gauges along the pacific coast. It shows that some of the tide gauges with shorter records in the Canadian coasts, display linear trend values which is close to their longer counterparts in the US tide gauges when the method of differencing is used.
The US tide gages in the east were incorporated individually in the VCM, and the lake level gauges in the Great lakes were considered in the differencing mode.

Table. 1 *Sea level linear trends and the standard deviations of the tide gauges on Pacific ocean (in mm/yr).*

No	Station	Latitude	Longitude	Point Velocity (mm/yr)	Velocity based on differencing (mm/yr)	Data available for this study
1	Tofino	49º 09´.0	-125º 54´.6	-1.55±0.16	-1.55±0.16	1909-2002
2	Port Alberni	49º 13´.0	-124º 48´.6	-0.01±0.78	-0.37±0.32	1970-1997
3	Bamfield	48º 49´.8	-125º 07´.8	+0.37±0.62	+0.92±0.19	1970-2002
4	Port Renfrew	48º 33´.0	-124º 25´.2	+1.24±0.69	+1.57±0.36	1957-1997
5	Sooke	48º 22´.2	-123º 43´.2	+1.95±1.41	+0.82±0.52	1958-1985
6	Victoria	48º 25´.2	-123º 22´.2	+0.08±0.36	+0.73±0.14	1925-2002
7	Patricia Bay	48º 39´.0	-123º 27´.0	-0.31±0.69	+1.01±0.19	1966-2002
8	Fulford Harbor	48º 46´.2	-123º 27´.0	+0.16±0.35	+0.24±0.36	1952-1992
9	Stevenson	49º 07´.2	-123º 10´.8	+2.10±0.60	+1.27±0.39	1969-1997
10	Vancouver	49º 17´.4	-123º 06´.6	+0.30±0.10	+0.30±0.10	1909-2002
11	Point Atkinson	49º 20´.4	-123º 15´.0	+0.85±0.12	+0.80±0.10	1914-2002
12	Campbell river	50º 01´.2	-125º 13´.8	-2.00±0.51	-1.58±0.20	1958-2003
13	Alert Bay	50º 34´.8	-126º 55´.8	-1.62±0.62	-1.22±0.63	1948-1979
14	Port Hardy	50º 43´.2	-127º 29´.4	-1.06±0.44	-0.65±0.21	1964-2002
15	Bella Bella	52º 09´.6	-128º 08´.4	-0.34±0.31	-0.89±0.19	1906-2002
16	Queen Charlotte City	53º 15´.0	-132º 04´.2	-0.88±0.34	-0.88±0.34	1957-2002
17	Prince Rupert	54º 19´.2	-130º 19´.2	+1.04±0.14	+1.04±0.14	1909-2002
18	Friday Harbor,WA	48º 33´.0	-123º 00´.6	+1.24±0.20	+1.07±0.19	1934-1999
19	Toke Point,WA	46º 42´.6	-123º 57´.9	+2.82±1.05	+1.20±0.47	1973-1999
20	South Beach, OR	44º 37´.2	-124º 02´.5	+3.51±0.73	+2.34±0.54	1967-1999
21	Seattle,WA	47º 36´.3	-122º 20´.4	+2.11±0.10	+2.11±0.10	1898-1999
22	Port Townsend, WA	48º 06´.6	-122º 45´.6	+2.82±0.88	+2.13±0.12	1972-1999
23	Port Angeles, WA	48º 07´.5	-123º 26´.4	+1.49±1.10	+0.37±0.17	1975-1999
24	Neah Bay,WA	48º 22´.2	-124º 37´.2	-1.41±0.22	-1.41±0.22	1934-1999
25	Charleston,OR	43º 20´.7	-124º 19´.2	+1.74±0.87	+0.48±0.55	1970-1999
26	Astoria,OR	46º 36´.3	-123º 46´.2	-0.16±0.24	-0.16±0.34	1925-1999
27	Cherry Point,WA	48º 51´.6	-122º 45´.6	+1.39±0.94	-0.03±0.14	1973-1999

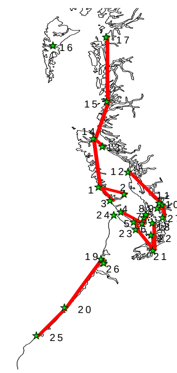

Figure 3: The optimum networks for differencing. Stars shows the tide gauges, and the solid red lines depicts those tide gauges which are more correlated.

Incorporating the US re-levelling data in map of VCM in Canada:

In the compilation of the map of VCM, the height difference differences of a relevelled segment and lake level differences between pairs of water level gauges supply the gradients of the linear vertical velocity surface. The procedure involves the use of all the data simultaneously, therefore, the US re-levelling data are going to be put in the same pot as Canadian geodetic data.

Discussion and conclusion:

Preliminary study of the combined network of differencing of Canadian tide gauges and US tide gauges on the Pacific ocean shows the advantages of such incorporation in improving the standard deviations of the shorter records of some of the tide gauges on the Canadian side. The area is a region of enhanced seismic hazard and is the focus of a variety of geodetic investigations and postglacial modeling. The results shown in Table 1 can be interpreted in terms of different processes, mainly plate-boundary related crustal deformations and glacial isostasy, and open new doors into the selection of optimum models of postglacial rebound models in the region which can explain relative sea level changes at this subduction zone. This is an ongoing study and needs further investigation.

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